BACK

# Dam-Breach Modeling and Flood Routing: A Perspective on Present Capabilities and Future Directions

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## EXTENDED ABSTRACT

Dam-breach modeling and the associated routing of the breach unsteady outflow through the downstream river/valley is a continuing concern to many Federal, state, and local agencies, other Nations, the private sector, and academia; these entities either are charged with or assist those so charged with dam design, operation, regulation, and/or public safety. A brief historical summary of many of the relevant developments aimed at the prediction of dam-breach floods and their extent of flooding within the downstream river/valley are depicted in Table 1. A further description of the contents of Table 1 follows.

Dam-breach modeling can be conveniently categorized as parametric-based or physically based. The former utilizes key parameters: average breach width ($\underline{b}$)[1] and breach formation time ($t_f$) as shown in Figure 1 (e.g., Fread 1971,1977,1988; Fread and Harbaugh 1973) to represent the hydraulics and breach formation in earthen dams, and thus compute the breach outflow hydrograph using a numerical time-stepping solution procedure or a single analytical equation $Q_p = 3.1\, \underline{b}\, [C/(t_f + C/\sqrt{H_d})]^3$ in which $Q_p$ = peak breach discharge, $H_d$ = dam height, $C = 23.4\, S_a/\underline{b}$ where $S_a$ = surface area (Fread 1981; Fread et al. 1991). Statistics on observed values for $\underline{b}$ and $t_f$ have been presented by Singh and Snorrason (1982) and Froehlich (1987,1995). Also, other analytical equations were presented by Singh and Quiroga (1988). Others (e.g., Hagen 1982; Evans 1986; Costa 1988; Froehlich 1995; Walder and O'Connor 1997) have used various regression equations to compute the peak breach discharge using only the reservoir volume ($V_r$) and the dam height ($H_d$) or some combination thereof (e.g., $Q_p = aV_r^b H_d^c$ in which a, b, and c are regression coefficients).

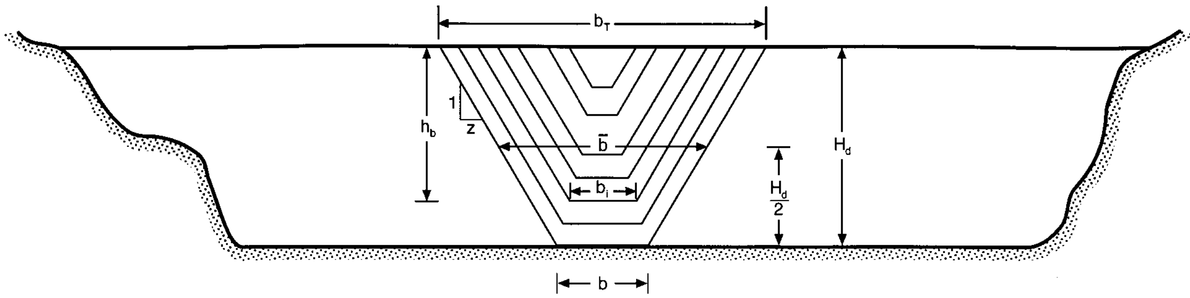
Physically based breach models use hydraulic, sediment erosion, and soil stability principles to construct time-stepping solutions of the actual breaching process and the breach outflow hydrograph (e.g., Ponce and Tsivoglou 1981; Fread 1984, 1987; Singh et al.1988; Macchione and Sirangelo 1988; Bechteler and Broich 1993).

Dam-breach flood routing models (e.g., DAMBRK and FLDWAV) have utilized (1) numerical solutions of the complete one-dimensional St. Venant equations of unsteady flow (e.g., Fread 1977,1988, 1993); (2) peak breach discharge attenuation curves coupled with the Manning equation to compute peak flow depths, e.g., SMPDBK (Wetmore and Fread 1984; Fread et al.1991); and (3) simplified Muskingum-Cunge routing and Manning equation depth computation, e.g., BEED (Singh et al. 1988). The latter two routing approaches incur additional error compared with the St. Venant-based routing; errors (less than 10 percent

[1]Editor's note: Due to software problems, $\underline{b}$ is used in the text to designate avearge breach width, while b with an overstrike is used in the figures.

| Year | DAM-BREACH OUTFLOW: Parametric, Numerical | DAM-BREACH OUTFLOW: Parametric, Analytical | DAM-BREACH OUTFLOW: Physical/Numerical Erosion/Collapse/Hydraulics | DAM-BREACH FLOOD ROUTING |
|---|---|---|---|---|
| 1969-71 | $Q = f(t_f, S_a, Q_l)$ Fread | $Q = f(\bar{b}, t_f, H_d, S_a)$ Fread | - - - - | - - - - |
| 1977 | NWS DAMBRK Last version: 1991 | - - - - | - - - - | NWS DAMBRK Last Version: 1991 1 - D |
| 1981 | - - - - | $Q = 3.1\ \bar{b}_r \left(\frac{C}{t_f + C/\sqrt{H_d}}\right)^3$ $C = 23.4\ S_a/\bar{b}$ | - - - - | NWS SMPDBK Last Version: 1991 Curves From DAMBRK |
| 1981-88 | - - - - | $Q = f(H_d, V_R, \ldots)$ Hagen, McDonald, Evans, Costa 1982 1984 1986 1988 | Ponce/Tsivoglou 1981 Erosion/Hydraulic 1 - D | - - - - |
| 1983-84 | - - - - | - - - - | NWS BREACH Last Version: 1991 | - - - - |
| 1987 | - - - - Statistical Data on Parameters Froehlich, 1987, 1995 | | - - - - | - - - - |
| 1988 | - - - - | Singh/Quiroga | BEED (Singh, et al.) 1-D/Sed (Macchione/Sirangelo) | BEED (Muskinqum - Cunge) |
| 1993 | - - - - | - - - - | 2-D/Sed (Bechteler/Broich) | - - - - |
| 1995 | NWS FLDWAV same as DAMBRK | - - - - | - - - - | NWS FLDWAV 1 - D Multi - River |

Table 1. Brief Summary of Developments in Dam-Breach Outflow and Flood Routing.




**$\bar{b}$ = Average Breach Width**

**$t_f$ = Time of Breach Formation (Time of Failure)**

**z = Side Slope of Breach 1:z (Vertical : Horizontal)**

**$H_d$ = Height of Dam**

**b = Bottom Width of Breach = $\bar{b}$ - z $H_d$**

Fig 1 - Parametric Representation of Dam/Breach with Parameters ($\bar{b}$, $t_f$, z)

for uncomplicated flood routing conditions) associated with the use of (2) were described by Fread et al. (1991), and errors of unacceptable magnitude for river bottom slopes less than 0.003 ft/ft inherent with the use of (3) were also determined (Fread and Hsu 1993). Flood routing is essential for assessing the extent of downstream flooding due to dam-breach outflows because of the extreme amount of peak attenuation that such unsteady flows experience during propagation through the downstream river/valley.

Future research/development directions to most efficiently and effectively improve the prediction capabilities for dam-breach floods are judged to be the following, in order of priority:

- Use prototype physical experiments to develop breach predictors for embankment dams including both breach “initiation” time and “formation” time; first, for clay embankment dams (Temple and Moore 1997), but also for silt/loan embankments, sand/gravel embankments, and embankments with clay or concrete seepage-prevention cores;

- Determine the Manning n flow resistance values for dam-breach floods using both historical data from such floods and theoretical approaches; also, determine procedures to account for flood debris blockage effects on Manning n values and the damming effect on bridge openings; and

- Develop methodologies, e.g., Monte-Carlo simulation (Froehlich 1998), to produce the inherent probabilistic features of dam-breach flooding due to uncertainties in reservoir inflows, breach formation, and downstream Manning n/debris effects.

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